

An Overview of the MEMS Fabrication Infrastructure

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MEMS Infrastructure Overview

- “There is plenty of room at the bottom.”
Richard Feynman
- However, how do we work at the bottom?
- Micro-electro-mechanical-devices (MEMS)

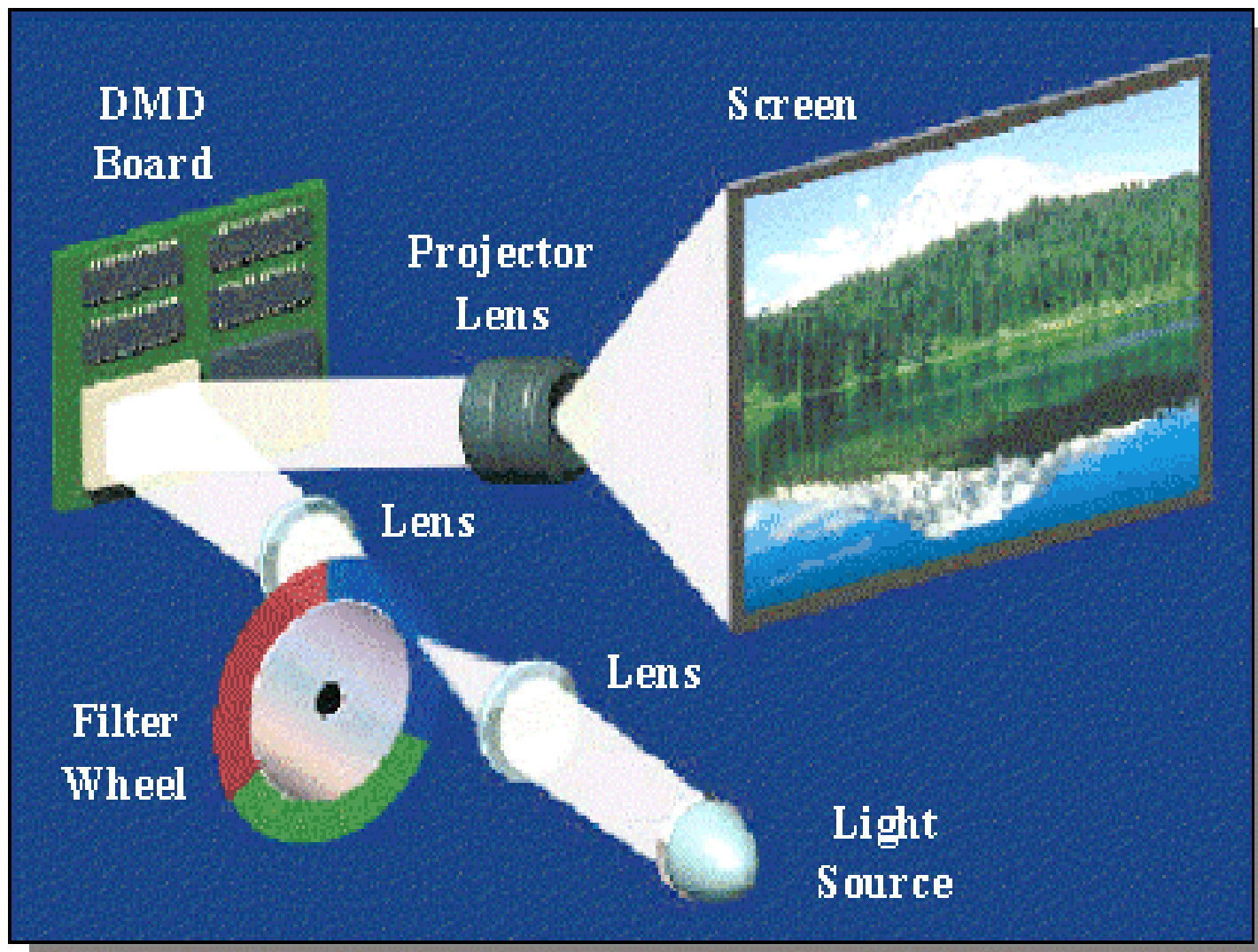
MEMS Devices

- Similar to larger scale devices and comprise:
 - Sensors
 - Actuators
 - Processor
- Example, Digital Micro Mirror Device (DMD) by Texas Instruments



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MEMS Devices



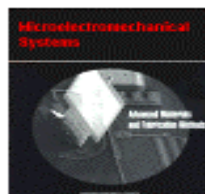
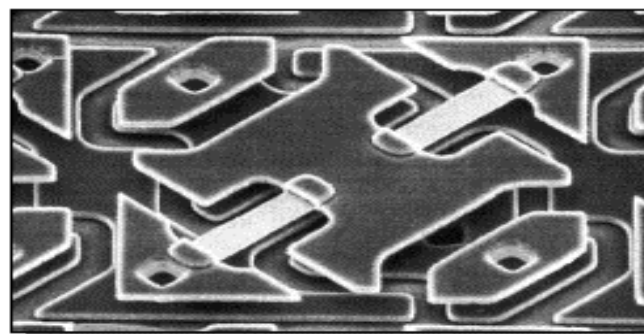
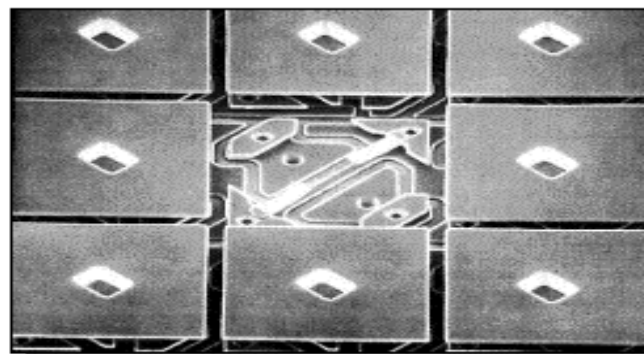
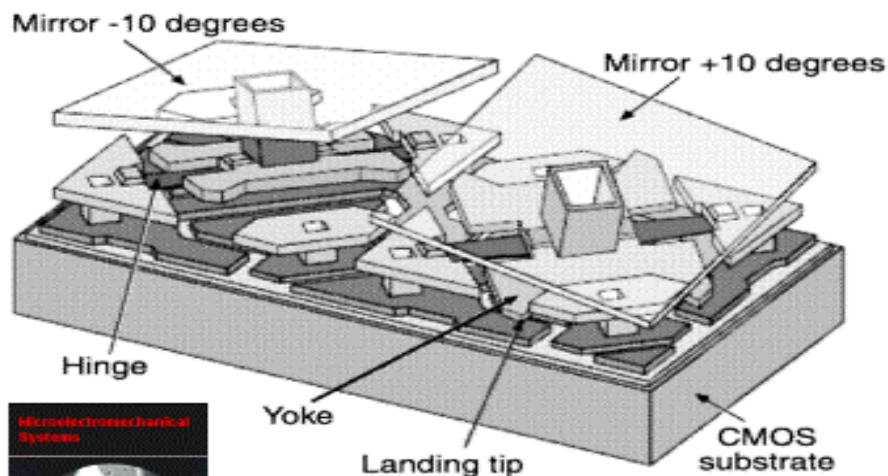


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MEMS Devices



Digital Micromirror Device



TEXAS INSTRUMENTS

National Research Council,
Microelectromechanical Systems:
Advanced Materials and Fabrication
Methods, National Academy Press,
Washington DC, 1997.

Commercial bistable micromirror
arrays (on/off) have been used in
numerous projection systems.



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Promises

As with all emerging technologies, the MEMS industry had been predicted to revolutionize technology and our lives.



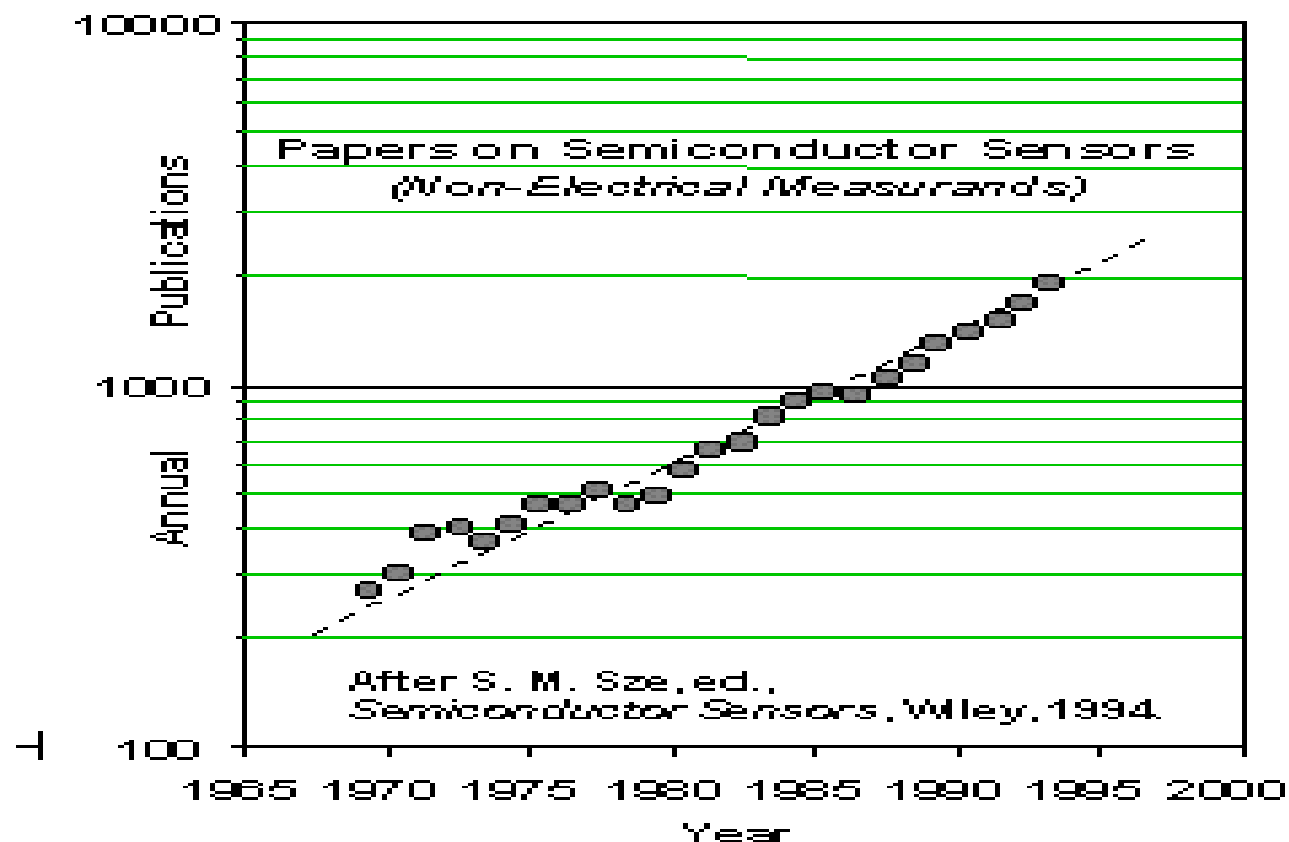
Promises Kept

- Significantly lower manufacturing costs
- Small inertial mass
 - shock resistance
 - higher band width
- Particularly realized in the area of:
 - sensors
 - signal switching



Promises Broken

Exponential Growth of Annual Semiconductor Sensor Papers!



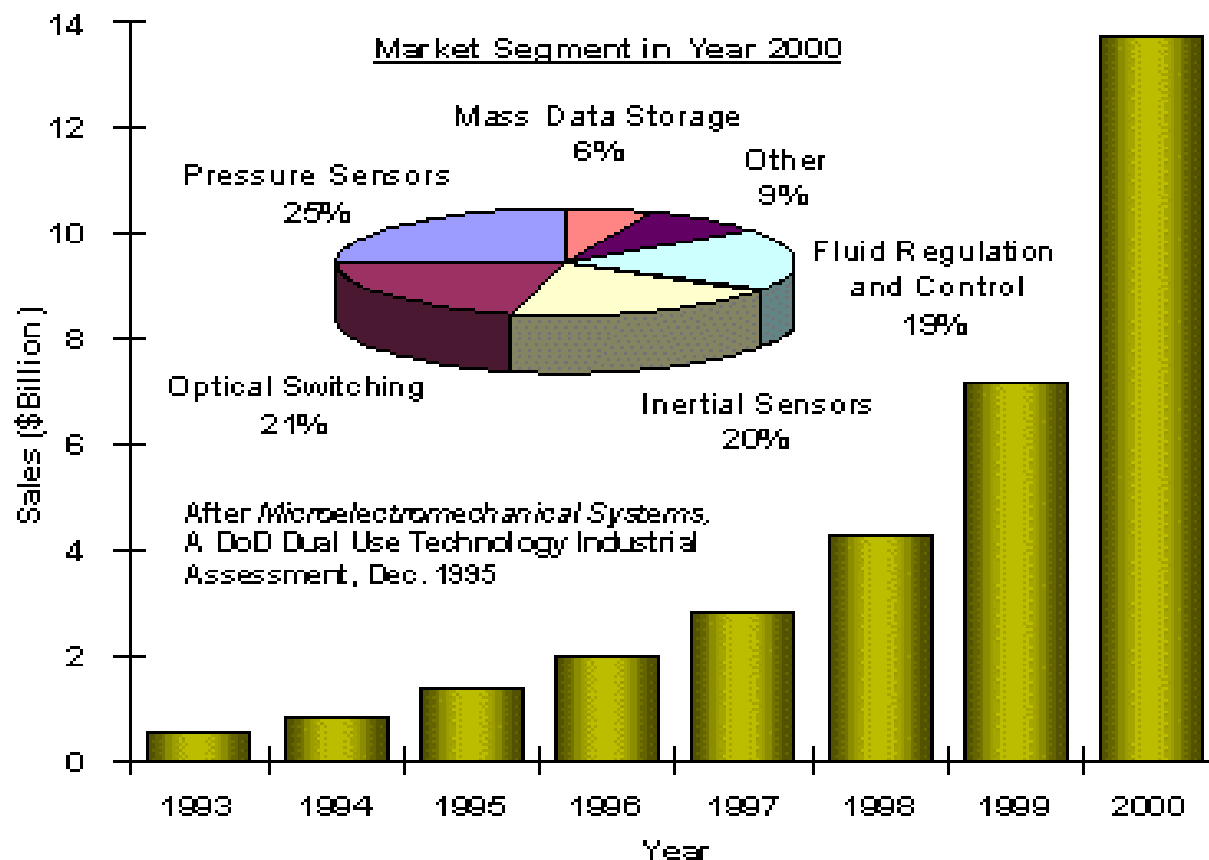


Promises Broken

MEMS has promised to revolutionize many aspects of life. The promise has lead to an increased interest in MEMS sensors. However, the MEMS field as a whole has not delivered on its promises.

MEMS Market Forecast 1995

Exponential Growth of MEMS Market with Projected
Year 2000 Sales to Approach **\$14 Billion** Worldwide!

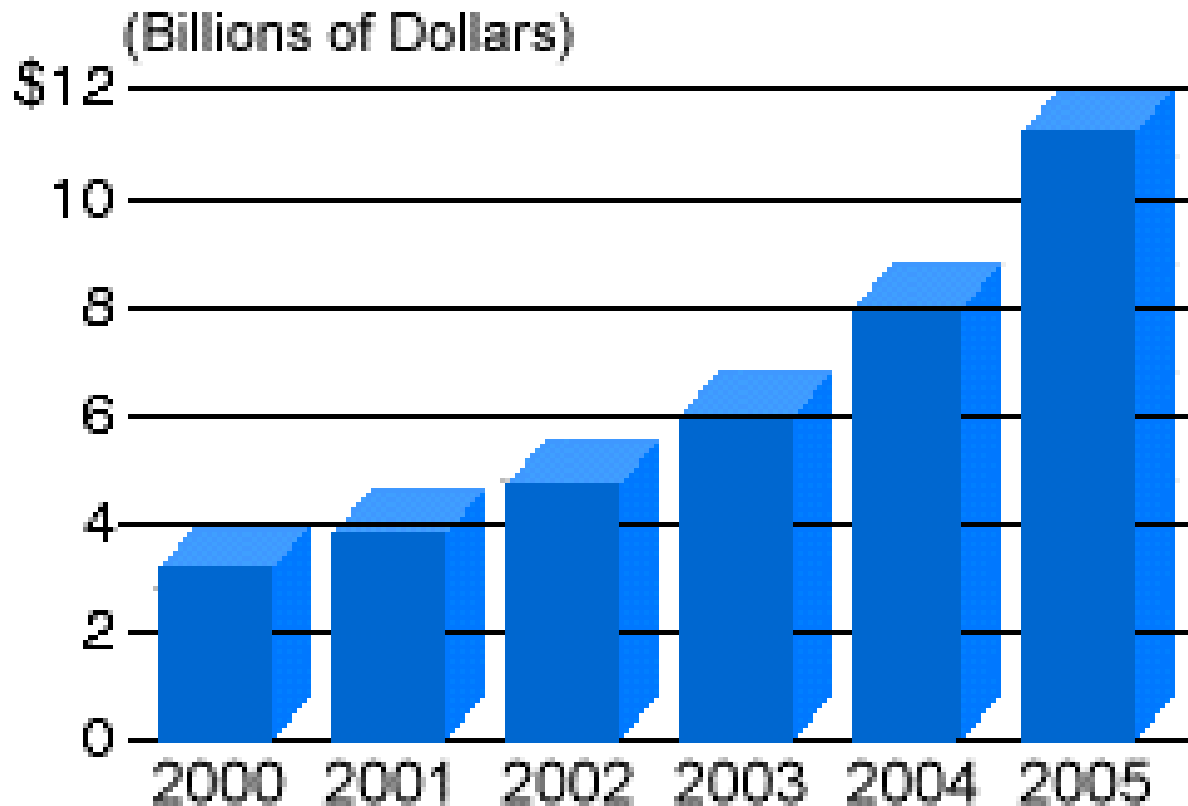




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MEMS Market Forecast 2000

Worldwide Forecast for MEMS



Source: Cahners In-Stat Group

Technical Limitations

- Difficulty in developing MEMS processing technologies underestimated
- Functionality difficulties normally not an issue with macroscopic devices
- Requirements for components and sub systems overlooked (packaging MEMS devices)
- Relatively imprecise devices

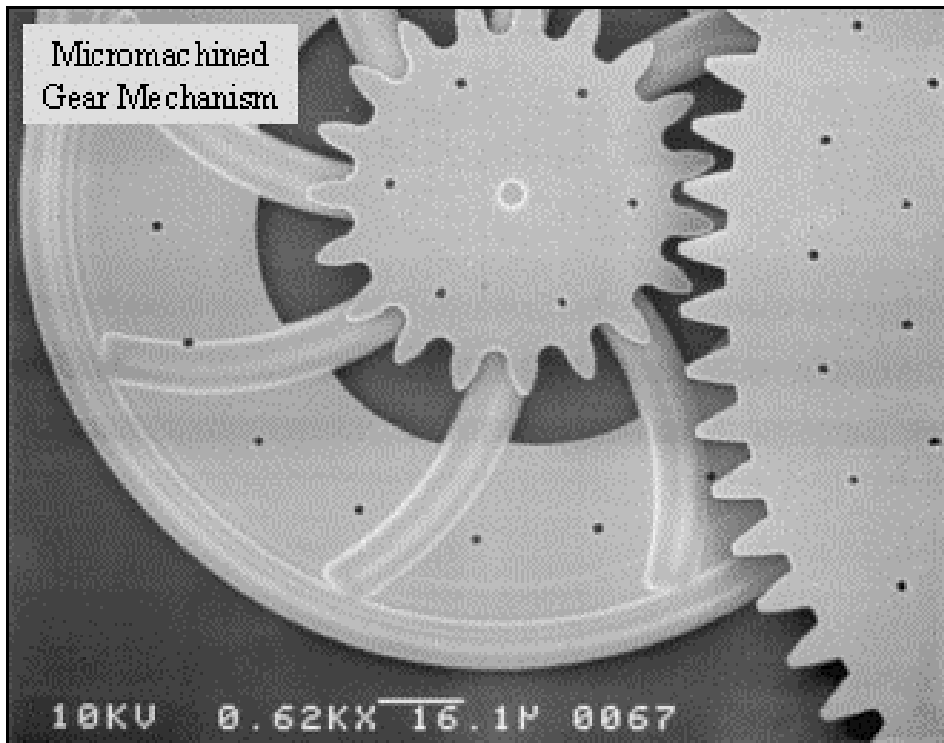
Small but Fairly Imprecise

Design rules determine initial separation!

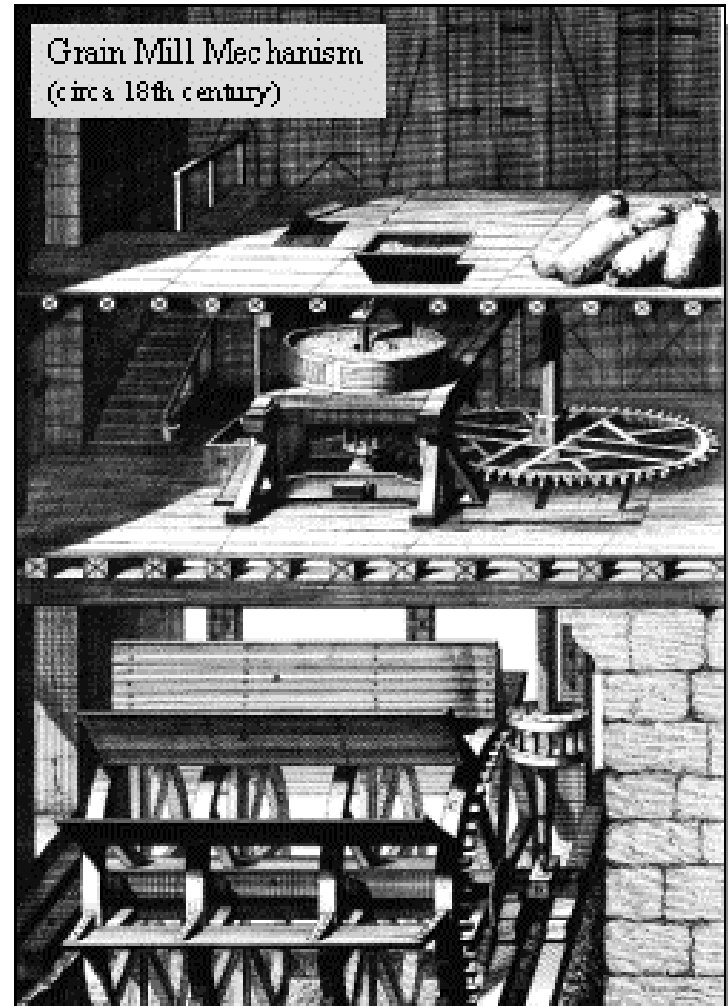
Features masked in the same layer must have a minimum separation distance between them. As a result, interlocking micromechanical devices have the same scaled tolerance as 18th century mechanisms.

J. H. Comtois, Air Force Research Laboratory, 1998.

Micromachined
Gear Mechanism



Grain Mill Mechanism
(circa 18th century)





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MEMS Promises

In light of the inflated market expectations, we do not want to discount the advances and improvements MEMS devices have provided.

MEMS Advantages and Limitations

Advantages

Batch processing methods
Low cost devices

Small Size and Weight
Shock resistance

Integrated with CMOS
High band width and
Better control of actuators

Limitations

Imprecise fabrication methods

Absence of foundry facilities

Nascent processing technologies

Expensive and complex packaging

CAD Design tool inaccuracies

Fabricating MEMS Devices

- Captive foundries
- R&D Prototype Facilities
- Commercial Production Facilities

MEMS Foundry Facilities

- To a large extent, MEMS foundries have focused on Silicon based processes.
- Many Silicon MEMS foundries are a second life for otherwise obsolete semiconductor technology. Supplemented with MEMS specific equipment.
- Processes using other materials remain relatively undeveloped by comparison.

MEMS Prototype Facilities

- Several foundries offer services
 - CRONOS (MUMPS)
 - Coventor (MPW)
 - MEMS Exchange (consortium with foundry like services)
 - Tanner Research
- Each foundry service offers certain kinds of MEMS processes.

- Supplier data base survey:
 - www.cmc.ca/Fabrication/Micromachining/micromachhp.html
 - home.earthlink.net/~trimmer/mems/Stroud_Dbase.html
- 10k units/month “high aspect ratio”
- Thirteen potential sources identified
- Four sources positive response

Commercial MEMS suppliers

Supplier	Processes
Goodrich Aerospace	<ul style="list-style-type: none">• Si bulk and surface
JDS Uniphase	<ul style="list-style-type: none">• Si bulk and surface• Limited UV LIGA• Capability for X-ray LIGA
Standard MEMS	<ul style="list-style-type: none">• Si bulk and surface• Integration of active electronic devices
Honeywell, ISPR	<ul style="list-style-type: none">• Si bulk and surface• Wafer bonding

Commercial MEMS Foundries

Common Themes

- R&D work must lead to significant production volumes
- Designs must be suitable for suppliers processes
- Engineering services available
- Porting unlikely
- Availability and lead times dependent on work loads
- Will not risk process contamination

Closing Remarks

- “...the MEMS industry right now is in the same state as the semiconductor industry was 35 years ago.” Finke, D., MEMS are Changing the Rules, ECN, May 15, 2000.
- “The IC world has a couple of standardized processes... bipolar, BICMOS, or CMOS. We don’t have that Luxury.” Richter, A., MEMS: Tiny Parts, Big Profits?, Semiconductor, August 2001.

Closing Remarks

- DOD techniques and process not necessary for the commercial market place will need to be developed.
- DOD system level considerations such as packaging and energetics will need to be developed.